U. S. DEPARTMENT OF AGRICULTURE

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COMMON WHITE GRUBS

WHITE GRUBS, the young of May beetles, are capable of devastating, and frequently destroy, large acreages of farm crops by eating the roots and underground portions. The crops damaged include two of our most important staples, namely, corn and potatoes. The adults—the beetles—eat the leaves of certain trees.

These insects require three years to complete their life cycle and usually only one brood is destructively abundant in a given locality. An abundance of May beetles one year indicates an abundance of grubs the following year. The pictorial diagram on pages 14 and 15 shows the life cycle.

It should be remembered that injury from white grubs, as well as from many other pests of farm crops, can be prevented by correct farm practice, but that after corn or any field crop has become infested with them it is impossible to prevent further injury to that particular crop.

Records of definite broods have been obtained for the Northern States and there it is possible usually to be warned one or more years in advance of their appearance.

For brief practical directions regarding what to do to combat each stage of the white grubs, consult page 26.

Washington, D. C. Issued May, 1918; revised February, 1929

COMMON WHITE GRUBS[1]

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WHITE GRUBS AND MAY BEETLES

THE COMMON WHITE GRUBS, or "grubworms" as they are often called (see title-page illustration and fig. 1), are the young of the May beetles or "June bugs" (fig. 2). They feed on the roots of various plants and the tubers of the potato (fig. 1) and have been recognized for years as serious pests, especially to corn and timothy, but also to the strawberry and potato, to recently transplanted roses, and to nursery plantings, particularly those of conifers. The adult insects (the beetles) eat the leaves of oak, ash, hickory, poplar, elm, willow, locust, hackberry, walnut, and other trees, and when abundant sometimes completely strip large tracts of timber. The most destructive work, however, is that of the grubs, which often results in the complete loss of crops

FIG. 1.—White grub working in a potato tuber, Tabor, S. Dak., 1912

[1] *Phyllophaga* spp.

NOTE.—Mr. Davis, the author of this bulletin, resigned Apr. 30, 1919, but the present revision was prepared by him.

where the outbreaks occur. Though adults show a preference for certain food plants, from present information the grubs of different species do not appear necessarily to have different food habits. There are no authentic records of injury to such crops as alfalfa and clover, and from all observations small grains [2] are less attacked and injured than are corn, timothy, strawberries, beans, potatoes, and conifer seedlings.

OUTBREAKS OF WHITE GRUBS IN 1912 AND 1915

Probably the most serious outbreaks of white grubs in the history of American agriculture occurred in 1912 and 1915, following an abundance of May beetles in 1911 and 1914, respectively. Injury was reported from almost every section of the country north of the Ohio River and westward to South Dakota. In the West the center of abundance was in southwestern Wisconsin, while in the East it seemed to be located in northeastern Pennsylvania and southeastern New York. Infestation occurred, however, as far west as Tabor, S. Dak., and though no serious general injury was found west of eastern Iowa there were scattered occurrences in western Iowa and southern Minnesota. Throughout the southern third of Wisconsin and in northern Illinois the grubs were abundant, especially in the western portion of these sections. Many infestations were also reported from southern Michigan and scattered ones from northern Indiana and eastward through Ohio.

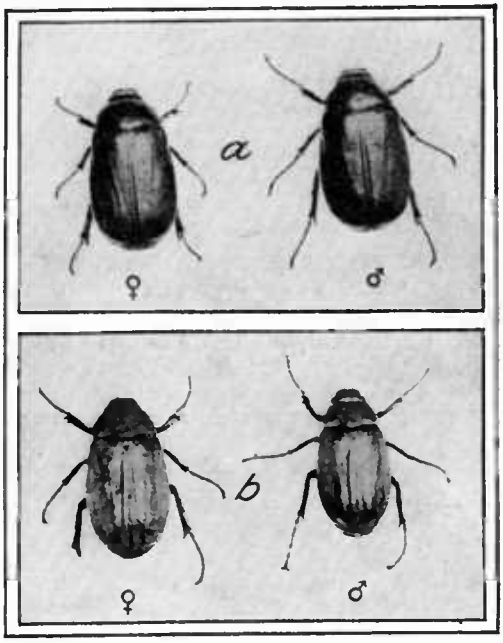


FIG. 2.—Typical examples of May beetles: *a*, *Phyllophaga anxia (dubia)*; *b*, *Phyllophaga ilicis*

White grubs have continued to be serious pests every third year over approximately the same area, and in 1927 the area of severe infestation increased in the middle West, especially in northern Illinois and Indiana, and apparently decreased in the extreme Eastern States. (Fig. 3.)

In the worst infested districts it is not unusual to find from 40 to 60 white grubs in a single hill of corn. Indeed, in a cornfield near

[2] Winter wheat is severely injured quite regularly in the fall in Kansas and Oklahoma by white grubs of one of the plains May beetles (*Phyllophaga lanceolata* Say). This insect, however, has habits and life history quite different from those of the common May beetles under discussion.

McGregor, Iowa, which had been planted to timothy the previous year (1911), 77 2-year-old grubs were found in the upper 5 inches of an area only 2½ feet square. This really represented an area less

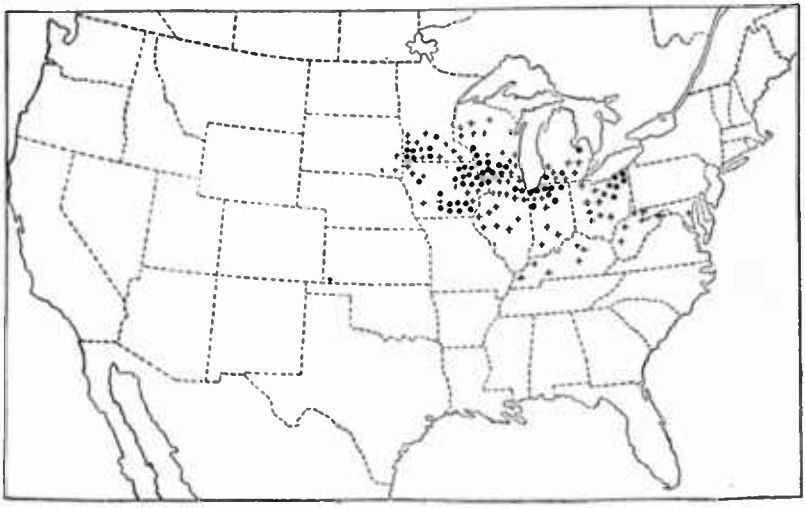


FIG. 3.—Map showing the extent of infestation by white grubs in 1927. The black dots indicate counties known to have been generally infested; the crosses, those known to have been infested more or less. Exact distribution records are not available for the Eastern States, but grubs were known to have been generally distributed in Pennsylvania and Virginia and in the southeastern part of New York

than that usually occupied by a single hill of corn, for the hills in this field were 3½ feet apart.

From a survey of the infested territory in Iowa (fig. 4), Wisconsin (fig. 5), and Illinois (fig. 6), made in 1912, and from reports of farmers and others, there is obtained a very conservative estimate of the damage to corn, timothy, and potatoes in these States aggregating

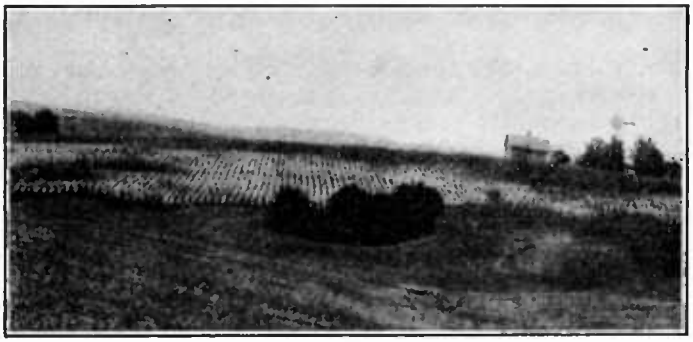


FIG. 4.—A 60-acre cornfield completely destroyed by white grubs, Farmersburg, Iowa, 1912

not less than $7,000,000. The damage to the same crops in the other infested districts could not have been less than $5,000,000, which brings the total loss due to white grubs in 1912, exclusive of damage

to strawberries, nursery stock, lawns, and miscellaneous crops, to not less than $12,000,000. A similar survey in 1915 showed a slightly smaller amount of apparent injury, although the beetles the preceding year were noticeably more abundant than in 1911 and the grubs were more numerous in 1915 than in 1912. The smaller amount of injury may be accounted for by the abnormally wet season which prevailed in this section in 1915, preventing the injury to crops and pastures which was so evident in 1912.

FIG. 5.—Individual corn hill showing characteristic white-grub injury, Platteville, Wis., August, 1915

POSSIBILITIES OF OUTBREAKS IN THE FUTURE

May beetles were unusually abundant in 1908, the grubs causing much damage in Wisconsin, Illinois, and other States in 1909 and again in 1912, 1915, 1918, 1921, 1924, and 1927. The beetles were very abundant in the spring of 1911 and again each year previous to the heavy grub infestation. These facts, together with the life-history cage experiments made by the Bureau of Entomology, give conclusive evidence that the life cycle of the more abundant and injurious species in those localities is uniformly three years. In the fall of 1916 the recently changed beetles were found very abundant in newly plowed ground in the white-grub areas just mentioned, but in the spring of 1917 the beetles did not appear until nearly three weeks after their normal date of emergence. Even after they had issued, the intermittent cool weather prevented them from completely defoliating large areas of timber as they did in 1914. Since the May beetles under discussion have a life cycle lasting for three years, future outbreaks of the grubs in these regions may be expected in 1930, 1933, etc.

BROODS OF MAY BEETLES

For the districts bounded roughly by the latitudes of northern Kentucky and southern Minnesota and from South Dakota on the west to Connecticut on the east the injurious and abundant species have a three-year life cycle, and the broods occurring in each of the three

years have been designated as broods A, B, and C, respectively. The brood issuing as May beetles in 1914 and appearing as destructive grubs in 1915 is brood A. (Fig. 7.) This is by far the most abundant of all known broods and is the one discussed under the preceding headings. The second brood (brood B), of which the beetles appeared in 1915 and the grubs in 1916, is of little consequence at present. The third brood, known as brood C (fig. 8), was active in the beetle stage in 1916 and the grubs destructive and abundant in 1917 in a few comparatively small districts.

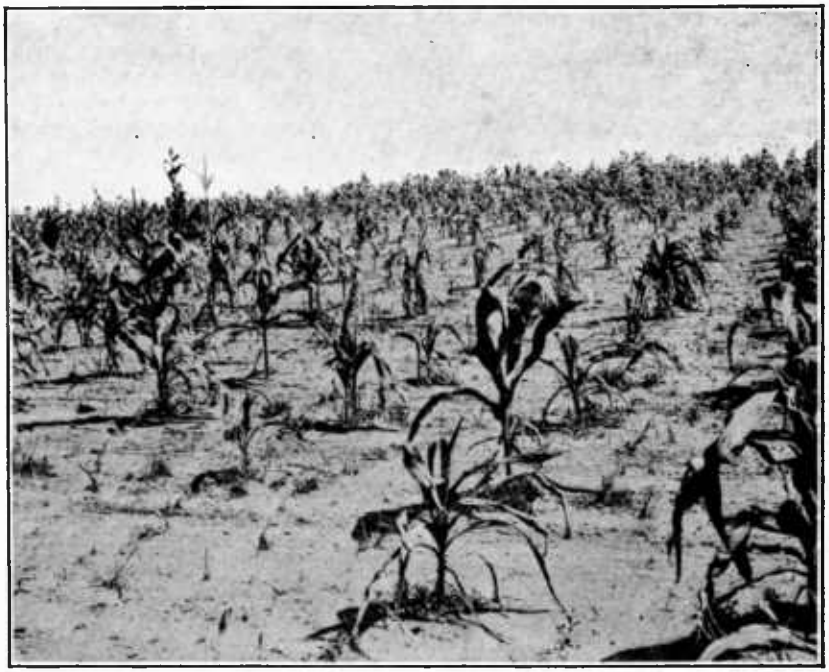


FIG. 6.—Cornfield injured by white grubs, Seward, Ill., August, 1915

LIFE HISTORY AND HABITS

All of the commoner species of May beetles have been reared from egg to adult at Lafayette, Ind. There the life cycle is three years, except in the case of several of the less important species. In the latitude of northern Wisconsin, where grubs of May beetles[3] are destructive to young conifers, the cycle is four years, and in the southern latitudes of Texas the period from egg to adult seems to be two years for most species. In the case of all of the common species occurring at Lafayette and northward the grubs change to adults in the fall, passing the winter in the soil as beetles and emerging the following spring. In several species[4] occurring in the latitude of southern Indiana and southward (species which appear late in the season and after the early appearing May beetles have about dis-

[3] *Phyllophaga drakii* Kirby (*grandis* Smith) and *P. anxia* Le Conte (*dubia* Smith).
[4] *Phyllophaga ephelida* Say, *P. forbesi* Glasgow, *P. quercus* Knoch, and others.

appeared) pupation and subsequent emergence as adults take place in the spring instead of in the fall.

A résumé of the life of the injurious generation of 1924 is as follows: Eggs (fig. 9) deposited by the female beetle in the spring of 1923 hatched three or four weeks later, and the young grubs fed the first season on decaying and living vegetable matter in the soil. As winter approached they protected themselves from the cold by burrowing deeper into the ground, remaining there inactive until the spring of the following year (1924), when they returned to a position near the surface, feeding on the roots of such crops as were available. In this, the second, year they did the maximum amount of damage. In the fall they again went deep into the soil, returning near the surface of the soil in the spring of 1925, where they fed as before on the plant roots until about June. Thus they passed two full years in the grub stage in the soil (fig. 10), and during this time they molted twice previous to molting for the pupa stage. They then prepared oval earthen pupal cells in the ground, became more or less inactive, and later changed to the pupa or true dormant state. (Fig. 11.) The adult beetles (fig. 2), which emerged from the pupae a few weeks later, remained in the pupal cells over winter and emerged the following spring (1926) to feed and mate in the foliage of the trees and shrubs and to deposit their eggs in the soil for the generation of grubs which was so severe in 1927. The complete life cycle of the insects is shown in diagram in Figure 16.

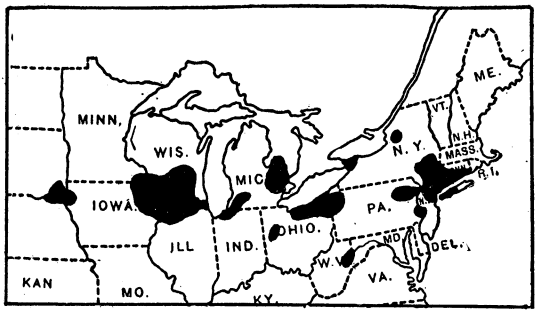


FIG. 7.—Map showing districts of greatest abundance of Brood A of white grubs. The extent of these districts and the amount of damage will vary somewhat from one outbreak to another

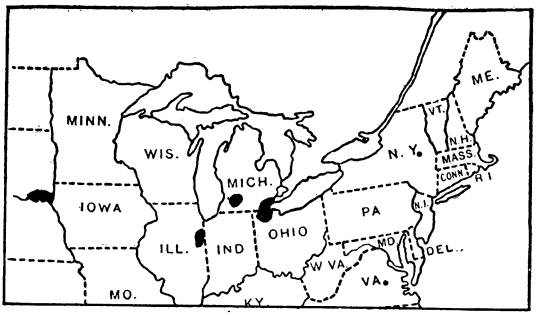


FIG. 8.—Map showing districts of greatest abundance of Brood C of white grubs

Unlike the grubs, the beetles of the different species differ as a rule in their food preferences. Certain species feed almost exclusively on the oak, others prefer the ash, and some feed indiscriminately. The trees which they ordinarily frequent in the Northern States are the oak (white and burr oaks in preference to red and black oaks), hickory, poplar, elm, willow, locust, hackberry, ash, and walnut. In certain localities the pine seems to be the preferred food.

At Columbia, S. C., two species[5] have been found feeding on the long-leaf pine by preference, and similar observations for these two species as well as for another[6] have been made in Alabama.

In the latitude of Indiana May beetles make their first appearance the last of April or first of May and continue to be present until the first or middle of July, the period of greatest abundance being between the middle and last of May. They swarm to the trees at dusk and remain there feeding and mating till just before dawn, when they return to the soil, only to reappear the following evening.

When abundant the beetles are capable of defoliating large acreages of timber. (Figs. 12 and 13.) In 1911, and again in 1914, 40-acre tracts of timber were completely defoliated by the beetles in southwestern Wisconsin, northeastern Iowa, northern Illinois, and south-

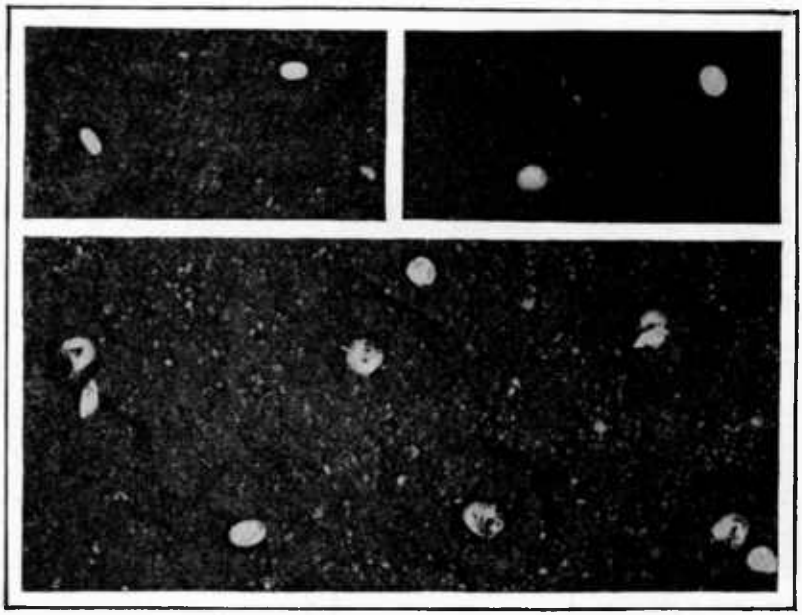


FIG. 9.—Eggs of white grubs in their natural cells; Upper left, immediately after deposition; upper right, six or seven days later; below, white grubs hatching

ern Michigan, and the dropping of excrement and of detached leaves at night, when the beetles were feeding, sounded like hail. The beetles, in the years of abundance, were attracted to street arc lights in great swarms, and in one small town in southwestern Wisconsin the beetles accumulating beneath the 10 arc lights of the town were hauled away each morning for a period of 10 days or 2 weeks by the wagonload.

The beetles (fig. 2) prefer to deposit their eggs in ground covered with vegetation in the immediate vicinity of timber, usually choosing for this purpose the more elevated parts. The preference in oviposition therefore has an important bearing on the control practices, for

[5] *Phyllophaga prununcultina* Burmeister and *P. luctuosa* Horn.
[6] *P. micans* Knoch.

the grubs ordinarily are found most abundant in the higher portions, especially near wooded tracts, of fields of timothy (fig. 10) and blue-grass sod, or in any ground which during the previous year was in one of these crops or in small grain, or any other ground which was covered with vegetation excepting clover during the flight of the beetles.

The eggs (fig. 9) are pearly white. When first laid they are elongate, measuring about one-tenth inch in length, but six or seven days after oviposition they become swollen and almost spherical. They are deposited in the soil at a depth ranging from 1 to 8 inches, within oval cavities in the center of balls of earth, the particles of earth forming the balls being held together by a glutinous secretion supplied by the female beetle.

FIG. 10.—A piece of sod overturned to show the white grubs underneath. Lancaster, Wis., 1912

After hatching the very young grubs seem to prefer decaying vegetation, although under certain conditions, especially when they are very numerous, they will attack living roots. This was the case in Wisconsin in 1911, when the young grubs, only about 2 months old, damaged timothy fields. (Fig. 10.) The grubs do the greatest amount of damage in their second year, and to the early plantings in their third year.

GRUBS LIKELY TO BE MISTAKEN FOR COMMON WHITE GRUBS

It is important that the grubs of May beetles should not be confused with similar but harmless grubs and with other grubs which may be injurious but which, because of different habits and life history, require different methods for their control. Probably the most universal mistake is the general belief that the common white grubs

of the field and the white grubs found in manure heaps and rotten logs are identical. The grubs of May beetles are not known to breed in manure or refuse of any kind. The most common grubs found in manure in the Northern States are the immature forms of certain brown beetles[7] which, like the May beetles, frequent lights, and would doubtless be mistaken for the latter by an inexperienced person, but unlike the latter the beetles do not feed on the foliage of plants. The May beetle grubs (fig. 14, *a*) may be distinguished from the manure grubs (fig. 14, *b*) and from most other grubs by the presence of a double row of more or less conspicuous spines along the median line on the underside of the last body segment.

Another grub commonly mistaken for that of a May beetle is the young of the southern green June beetle,[8] which frequently has been reported as indirectly injuring grass and other vegetation, including alfalfa, in localities south of the latitude of northern Kentucky, or even farther north along the Atlantic coast. The grub of the green June beetle seems to prefer soils more or less heavily fertilized with animal manures, and, besides, entirely unlike the common white grubs, it makes definite burrows which usually open at the surface and which it may inhabit continuously for longer or shorter periods of time. For this reason grubs of this species will come to the entrance of their burrows and even crawl out upon the ground when the land is flooded with water. This characteristic also offers a satisfactory means of controlling the grub of the green June beetle when in lawns or small areas. Again, this grub may be distinguished from the true white grubs by its general appearance and especially by its peculiar and characteristic method of crawling on its back when placed on the surface of the ground.

FIG. 11.—White-grub pupa in earthen cell. Natural size

NATURAL ENEMIES

The white grubs and May beetles are preyed upon by numerous birds, mammals, and insects, all of which are more or less useful in reducing their numbers. Probably the most important of the natural enemies are the birds, especially crows and crow blackbirds, and in some localities the gulls. Fields of timothy sod have been literally overturned by crows in their search for grubs (see fig. 15), and in some fields the grubs were almost exterminated by them. Crows have often been observed following the plow in infested fields, eagerly picking up every grub that was unearthed. In one instance a single blackbird was observed to eat many grubs, apparently its full capacity, and then gather as many as it could hold in its beak and fly away. In this case the bird destroyed in all 20 grubs in one or two minutes. Besides crows and blackbirds, practically all of the common birds feed on white grubs or their adult forms, the May beetles.

[7] *Lachnosterna gibbosa* DeGeer and *L. rectitis* Say. [8] *Cotinis nitida* Linnaeus

FIG. 12.—Walnut and soft maple, the former defoliated by May beetles, Galena, Ill., May 31, 1914

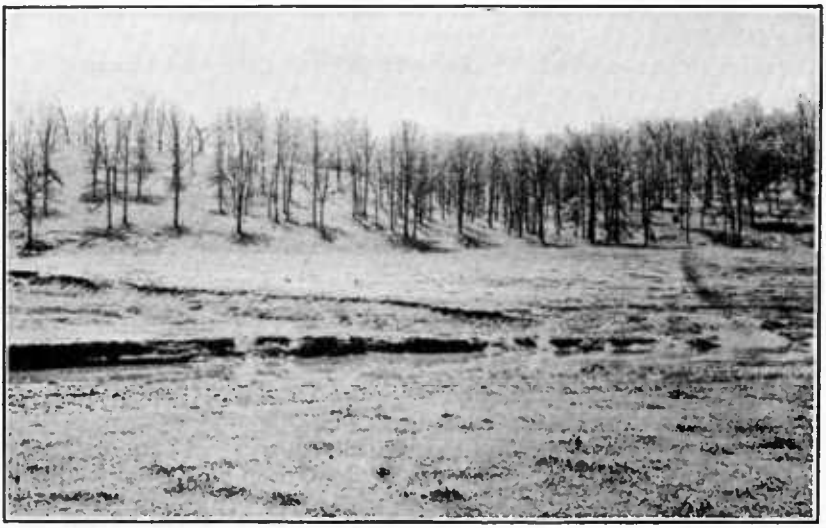


FIG. 13.—Hickory and oak timber defoliated by May beetles, Platteville, Wis., June 1, 1914

The Bureau of Biological Survey has found these insects in the stomachs of 78 species of birds and two species of toads.

All farm fowls are fond of these insects and where possible should have the run of infested fields at the time of plowing. The turkey especially is valuable in this respect. The writer has seen infested timothy and sod fields thoroughly scratched up by these birds in their search for grubs. Chickens seldom search unplowed fields for grubs, but if permitted to follow the plow will eagerly pick up every grub or May beetle exposed.

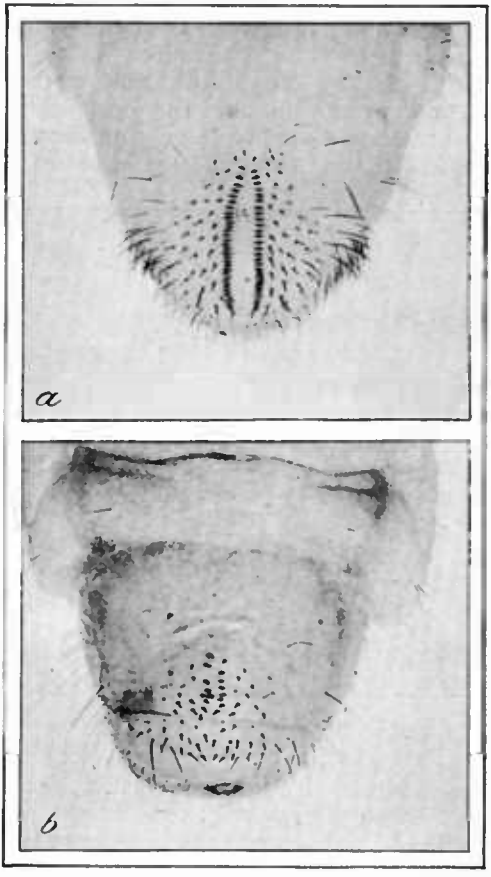


FIG. 14.—Last segments of the larvae of (*a*) common white grub and (*b*) a grub frequently found in manure

Among the native mammals which feed on the grubs the skunk is probably the most valuable,[9] and, indeed, some farmers have gone so far as to attribute the increase in these insects to the decrease in numbers of skunks, which are being rapidly killed off by the trappers. In northeastern Iowa many large landowners observed the grub-eating habits of the skunk during a severe outbreak, and signified their intention from now on of protecting this friend of the farmer.

A large number of predaceous and parasitic insects have been studied. Of these it is probable that such common and generally distributed forms as certain black digger wasps,[10] and another wasp,[11] are among the most beneficial.

The Tiphia wasp larva, after devouring the white grub, forms a characteristic cylindrical-ovate, light brown, woolly cocoon about three-fourths inch in length (fig. 17), and from this the jet black digger wasp emerges the following spring or summer. The cocoon of the Elis wasp (fig. 18) differs from the Tiphia cocoon (fig. 17) in that it is elliptical, slightly longer, of a darker brown, and comparatively smooth. The adult emerging therefrom is about the same size as

[9] The domestic hog is the most efficient of all grub destroyers where it can be utilized. It is fully discussed in this connection under "Methods of control," p. 13.

[10] *Tiphia* spp.

[11] *Elis* sp.

the Tiphia wasp, or slightly larger, and the black abdomen is transversely striped with yellow. The cocoons of both of these parasites are frequently turned out by the plow, especially in fields badly infested with white grubs. The larvae of flies,[12] parasitic on grubs, are numerous in certain localities, but since they are living within live grubs in fall, winter, and early spring, they are seldom noticed behind the plow. The larvae of robber flies,[13] which prey upon white grubs, are slender, shining white, pointed at both ends, and about an inch and a half in length when full grown. (Fig. 19.) They have a life cycle corresponding to that of the common white grubs in that they require three years to complete it. In certain sections of Wisconsin, Michigan, and New York they undoubtedly have been very important in minimizing the destructiveness of the grubs. When mature they issue as large flies commonly known as robber flies, bee killers, etc., and in this stage of their life are predacious on

FIG. 15.—Timothy field after harvest, showing sod overturned by crows in their search for white grubs. Galena, Ill., 1912

many kinds of insects. Certain parasitic flies[14] (fig. 20) attack only the beetle, usually depositing the egg within its body with a needlelike ovipositor as it flies from leaf to leaf or to the ground at night. The larva hatching from the egg gradually kills the beetle, although often the latter, if a female, is capable of depositing eggs for some days after being parasitized. Certain two-winged flies[15] are similarly parasitic on the adult beetle, but they oviposit on the beetle when it is quietly feeding on foliage at night.

Several fungous, bacterial, and animal parasite diseases have been reported attacking the grubs and beetles. Occasional outbreaks of these diseases have been observed, and it is highly probably that they serve as valuable natural checks periodically when conditions are

[12] *Microphthalma disjuncta* Wiedemann and *Ptilodexia tibialis* Desvoidy.
[13] *Promachus vertebratus* Say and *P. fitchii* Osten Sacken.
[14] *Pyrgota undata* Wiedemann and *P. valida* Harris.
[15] *Cryptomeigenia theutis* Walker, *Eutrixa exilis* Coquillett, and *Biomyia lachnosternae* Townsend.

favorable. In Europe certain of these diseases have been artificially grown and used to destroy the grub, but there seems to be a divergence of opinion as to their value when used in this manner. The experience of the writer indicates rather strongly that they can not be introduced artificially with satisfactory results except under favorable weather conditions.

FIG. 17.—Cocoon of a wasp, *Tiphia* sp., a parasite of the larvae of May beetles

METHODS OF CONTROL

All of the general farm practices here discussed and recommended are preventive rather than remedial, for once white grubs are present in a field of corn or other crop of large acreage there is no practical means as yet known of protecting that particular crop from their ravages. On the other hand, certain cultural and other practices will minimize greatly the damage in succeeding years.

UTILIZING HOGS AND POULTRY TO DESTROY GRUBS

The practice of "hogging off" corn, thereby saving the labor and expense of harvesting and marketing the crop and also producing more pork from the crop, is a common farm practice, the value of which has been repeatedly demonstrated. The utilization of hogs for the destruction of soil-inhabiting insect pests, more especially of white grubs and cutworms, however, has received little attention and seldom has been applied consistently, although pasturing hogs in grub-infested fields has been practiced occasionally for the last hundred years. The use of poultry is somewhat more restricted, since they can be utilized only when ground is being plowed or cultivated, and then only in fields near the farm buildings, unless a portable poultry house is used.

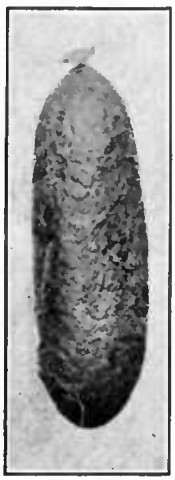
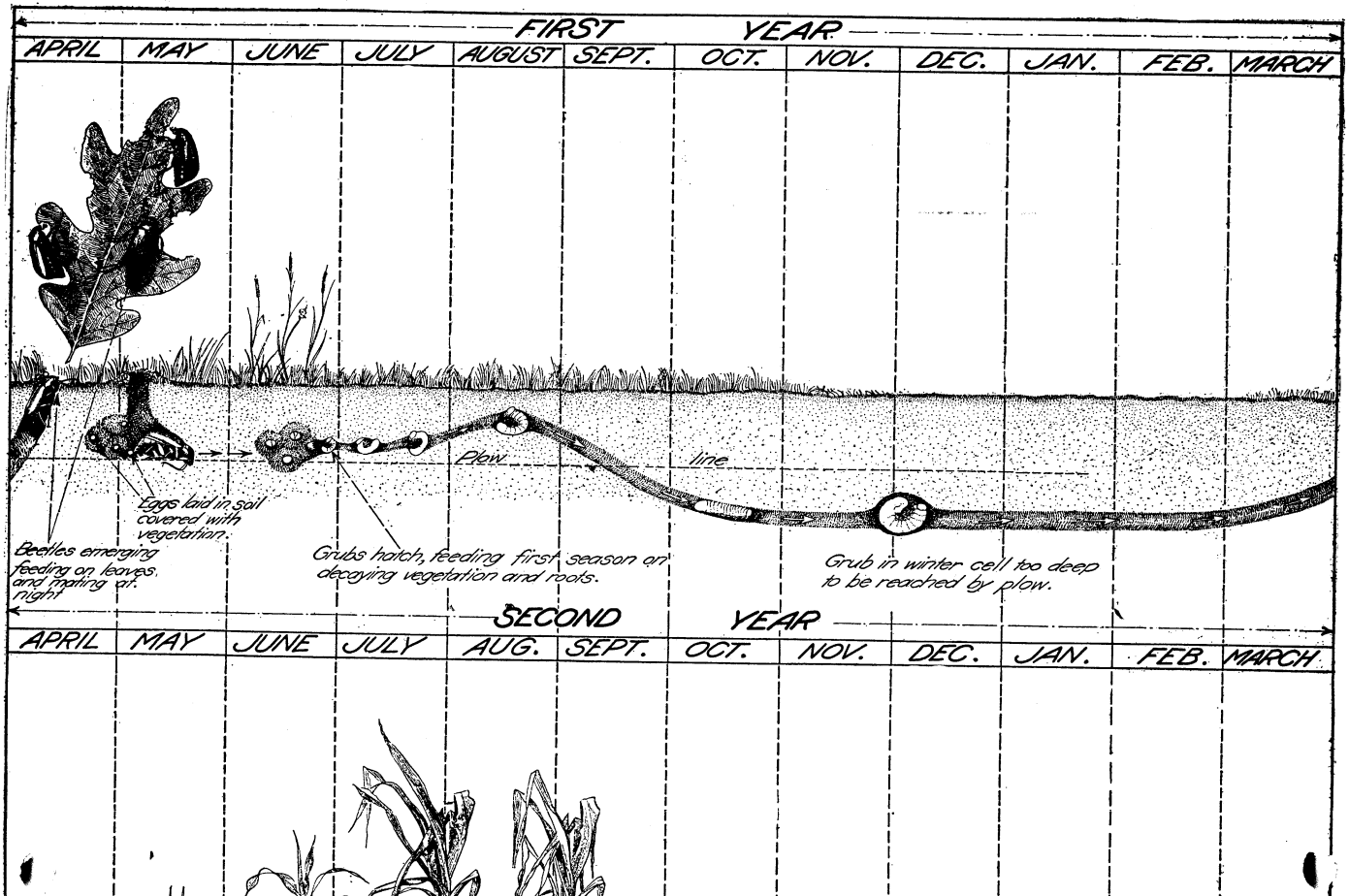


FIG. 18.—Cocoon of a wasp, *Elis* sp., a parasite of the larvae of May beetles

The main objects to be gained by the practices indicated above are (1) eradication of grubs, cutworms, and probably such other insect pests as wireworms; (2) food value derived from the grubs, which is equal to a hog feed costing $25 to $35 per ton; (3) manuring the land. The United States Bureau of Animal Industry has estimated the value of manure to be $3.29 a ton in the case of hogs and $7.07 in the case of poultry.[16] When corn ground is "hogged" there is the additional advantage of a saving in labor and expense in harvesting and marketing the crop and the production of more pork from the crop.

[16] Weekly News Letter, U. S. Department of Agriculture, v. 4, no. 17, p. 3. Nov. 29, 1916.


FIRST YEAR
APRIL
MAY
JUNE
JULY
AUGUST
SEPT.
OCT.
NOV.
DEC.
JAN.
FEB.
MARCH
Plow line
Beetles emerging feeding on leaves, and mating at night
Eggs laid in soil covered with vegetation.
Grubs hatch, feeding first season on decaying vegetation and roots.
Grub in winter cell too deep to be reached by plow.
SECOND YEAR
APRIL
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.
JAN.
FEB.
MARCH

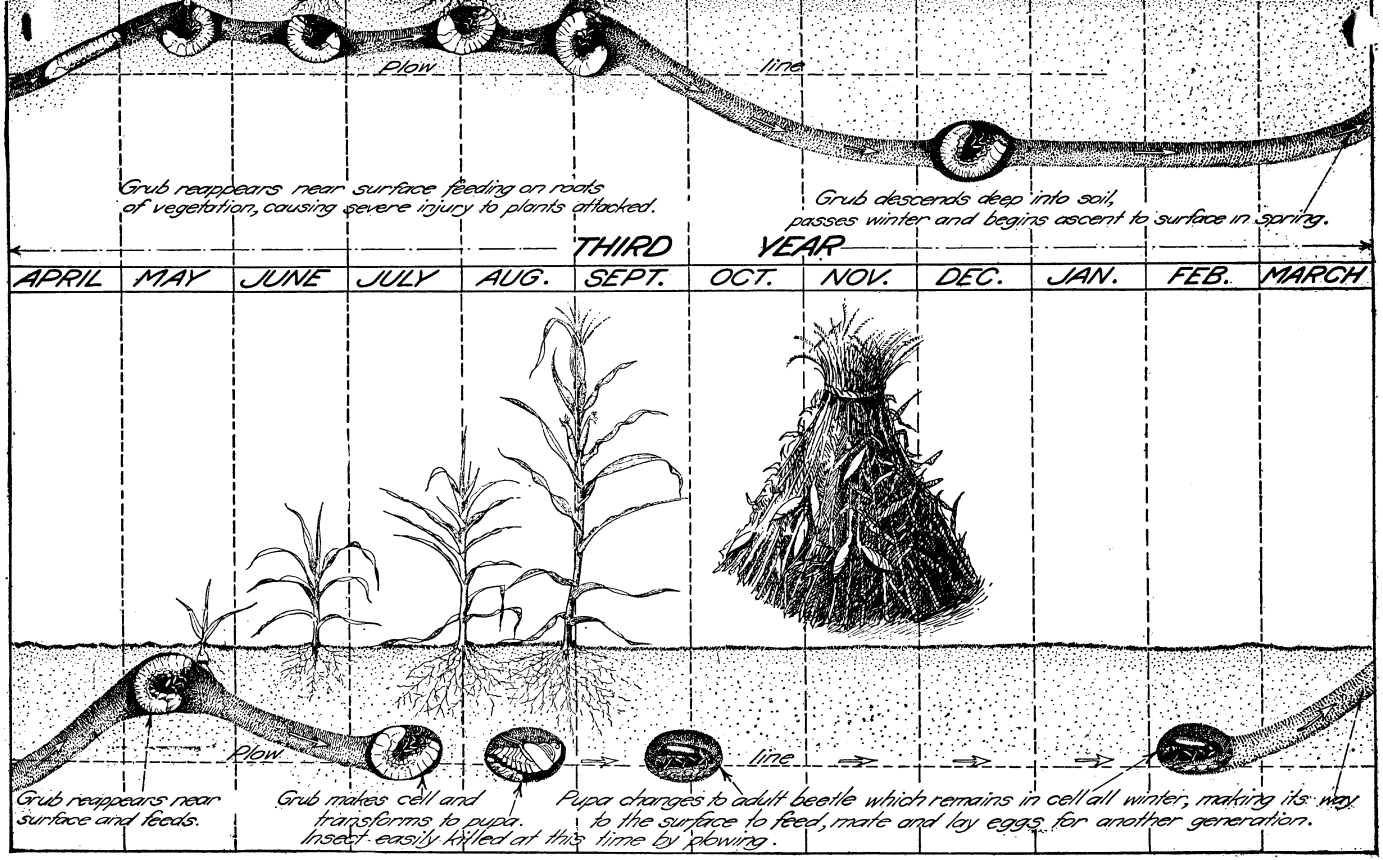


FIG. 16.—Diagram, which covers a period of three years, illustrating complete life cycle of white grubs and showing the periods during which they can be killed by plowing

EXAMPLES OF INSECT CONTROL BY HOGS AND POULTRY

The fondness of hogs for white grubs and May beetles is well known and evidenced wherever unringed hogs have been turned into pastures (fig. 21), but a most striking example has been shown.[17] One hundred pigs and eight sows were turned into an inclosed 10-acre cornfield at Ludlow, Ill., which was badly infested with grubs, September 23. Within 20 days 86 per cent of the grubs were destroyed and in 27 days less than 1 per cent of the original infestation remained—a benefit of over 99 per cent. If the number of grubs per hill is estimated at 34.6, the count made at the beginning of the experiment, and the number of hills of corn to the acre as 3,556 (hills 3½ feet each way), it is easily calculated that the pigs destroyed something like 1,217,083 grubs in 27 days; that is, 11,278

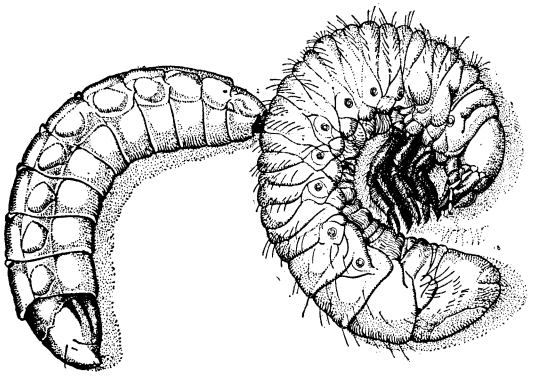


FIG. 19.—Larva of the robber-fly *Promachus vertebratus* attacking white grub

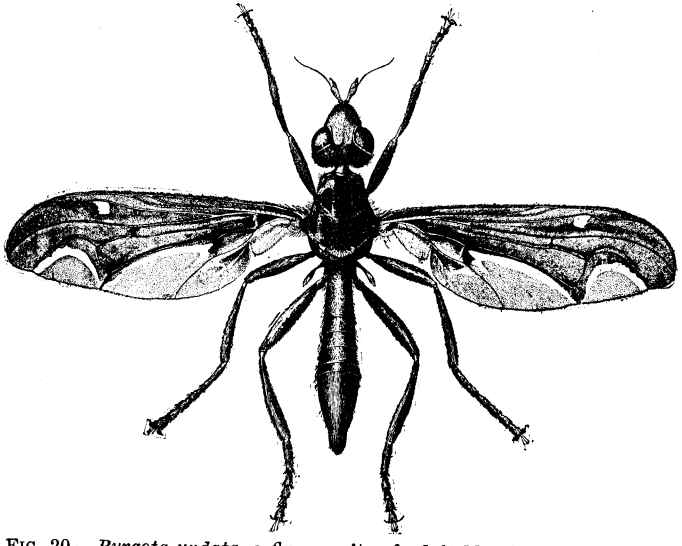


FIG. 20.—*Pyrgota undata*, a fly parasite of adult May beetles. Enlarged greatly

grubs, or possibly 24 pounds, per animal. These hogs, by the way, suffered no ill effects from the continuous ration of grubs.

Turkeys are very fond of grubs and search diligently for them.

[17] FORBES, S. A. ON THE LIFE HISTORY, HABITS, AND ECONOMIC RELATIONS OF THE WHITE GRUBS AND MAY BEETLES. Ill. Agr. Exp. Sta. Bul. 116, p. 478. Aug., 1907.

Poultry can be utilized to excellent advantage, especially if allowed the run of the fields during plowing or cultivation. The effectiveness of chickens in controlling white grubs is demonstrated by an experience at Froelich, Iowa, where the farm poultry, numbering about 150 chickens, were encouraged to follow the plow, harrow, and cultivator in a 15-acre field, badly infested with white grubs, adjoining the farm buildings. Scarcely a grub remained after a season's foraging by the chickens.

FIG. 21.—Hogs rooting for grubs in cornfield referred to on page 16. Photograph furnished by S. A. Forbes

VALUE OF WHITE GRUBS AND MAY BEETLES AS ANIMAL FOOD

Through the cooperation of the office of the Indiana State chemist, standard chemical feeding analyses of white grubs and May beetles of the genus Lachnosterna, now called Phyllophaga, have been made and these, together with an analysis of dent corn for comparison as given by W. A. Henry,[18] follows:

TABLE 1.—*Analysis of dent corn, compared with white grubs and May beetles*

Material	Grubs[a]	Beetles[b]	Corn
	Per cent	*Per cent*	*Per cent*
Moisture	79.9	69.4	10.6
Crude fat	3.1	4.9	5.0
Crude protein	11.1	20.1	10.3
Crude fiber	1.6	3.7	2.2
Crude ash	2.0	1.6	1.5
Nitrogen-free extract (carbohydrates)	2.3	0.3	70.4

[a] One and two year old grubs collected behind plow in fall of 1916.
[b] Recently matured beetles collected behind plow in fall of 1916.

[18] HENRY, W. A. FEEDS AND FEEDING. Madison, Wis. 657 p. 1909.

In comparison with such a standard feed as corn it will be noticed that in grubs the percentages of fat and protein, the most valuable foods in feeding material, about equal the percentages of these constituents in corn, while the percentages in beetles run much higher. The carbohydrates, on the other hand, are deficient in the insects; and this would indicate that the feeding of corn in connection with pasturing hogs in grub-infested land, or, better, "hogging down" corn if the infested field is in corn, is desirable and a good practice.

In the white-grub infested areas there is an average of 106,680 grubs per acre, and the weight of the grubs during the fall of their destructive season averages 1 gram each—that is, 454 to the pound—the beetles weighing slightly less. Thus it may be estimated that each infested acre contains approximately 235 pounds of grubs which have a value as hog food of more than $3—that is, $30 for 10 acres.

VALUE OF WHITE GRUBS AND MAY BEETLES AS MANURE

In addition to the value of grubs and May bettles as hog and poultry feed, the value of the manure produced should also be considered. As a general criterion the money value of hog manure has been estimated, as indicated above, at $3.29 and of poultry manure at $7.07 per ton. It is said [19] that during the life of the animal 85 per cent of the fertilizing constituents ingested by hogs as food is eliminated by the system in the urine and feces, the percentage being greater for mature individuals. By simplifying the protein constituents it is found that the grubs contain 1.78 per cent nitrogen and the beetles 3.22 per cent, and since each heavily infested acre is estimated to contain 235 pounds of the grubs or 157 pounds of May beetles it may be figured that approximately 3½ pounds of nitrogen alone would be replaced in the manure produced by the hogs eating the grubs, and 4½ pounds if the food were in the form of beetles. The ash, constituting 2 per cent of the grubs and 1.6 per cent of the beetles, is heavy in phosphoric acid, but the exact amount of this and other fertilizing elements has not been ascertained.

EFFECT RESULTING FROM CONTINUOUS GRUB DIET

Occasionally reports of harmful effects to hogs from a continuous grub diet have been received, but it has not been possible to verify them. On the other hand, well-informed farmers and expert swine raisers who have had experience in pasturing hogs on grub-infested land disclaim any harmful or poisonous effects from such practices.

Likewise poultry may be fed white grubs and May beetles without any harmful results and without producing any noticeable effect in the eggs, such as is noticed when chickens feed continuously for several days on such caterpillars as the army worm. No difference in taste has been found in European tests between eggs from grub-nourished hens and those from others. On the contrary, the eggs of the former had better yolks for thickening and were worth three of the others to color sauces. No unfavorable effects resulted from the

[19] GOOD, E. S. THE GROWING AND FATTENING OF HOGS IN THE DRY LOT AND ON FORAGE CROPS. Ky. Agr. Exp. Sta. Bul. 175, p. 332. Apr., 1915. (Statement of H. S. Grindley quoted.)

use of either grubs or May beetles as chicken feed, except in the case of dried beetles mixed with bread or potatoes, which proved too exciting for the older fowls.

OBJECTIONS MADE TO GRUBS AS ANIMAL FOOD

Three objections have been raised to the use of unringed hogs in grub-infested fields, most of which apply only in cases of pasturing on sod land. These objections are (1) lack of hog-tight fences; (2) rooting up of pasture land; (3) possible infestation with the giant thorn-headed worm,[20] an intestinal worm affecting hogs.

The first objection has been answered, for it has been shown that the value of the grub as hog feed almost pays for the cost of fencing—at least temporary fencing.

Observations by the author show that an infested pasture, although overturned by rooting hogs, reseeds itself the following season with no ill effect other than a roughing of the surface, which is of little significance.

The last objection, relative to possible infestation with the giant thorn-headed worm, is of considerable importance. The white grub is one of the intermediate hosts of this worm, which seems capable of entering hogs only by being taken into the body with grubs eaten. No trouble will result from these worms, however, if hogs which have never been pastured are used in fields which have not been previously pastured with hogs within three years. Care should be taken to prevent brood sows from running in fields which are likely to contain grubs infested with thorn-headed worms, that is, in fields which have been hog-pastured the previous season or two, but hogs being fed for market can, with the possible exception of very young pigs, be pastured with less regard for the past history of the field, since they will be marketed before the effects of the worms, if any are present, become harmful.

SUGGESTIONS FOR THE USE OF HOGS FOR WHITE-GRUB CONTROL

In the white-grub infested districts hogs may be used to advantage each year and in almost every season of the year. Figure 16 illustrates graphically the life cycle of this insect and should be used as a guide in pasturing hogs on infested ground. It should be noted that the grubs ordinarily go rather deep into the ground to pass the winter, usually starting their downward migration by October 10, so that it is desirable to practice fall pasturing previous to this date.

During the flight of the beetles hogs should be pastured in timber lots or fields adjoining so that they may have an opportunity to destroy the beetles. In the fall of the year the beetles are abundant and the hogs should be pastured in small-grain stubble, timothy, bluegrass, or weedy lands, for here the beetles have laid their eggs and the young grubs are to be found. The year following an abundance of beetles, which is the year the grubs are most destructive, pasturing after the first of May is desirable when it can be done conveniently, but before this date the effect of pasturing on the grub population is not so evident, since the ground is usually quite hard and the grubs

[20] *Echinorhynchus gigas.*

still in their winter quarters, often a foot or more below the surface. It has been shown that hogging corn is profitable and if the ground contains grubs it will be especially profitable for pasturing, since the combination of corn and grubs offers a fairly well-balanced ration. The third year, when the grubs mature and change to beetles, the hogs may be utilized at any time after May 1, and it is especially desirable to pasture them in ground which showed an abundance of grubs the preceding year.

As has already been inferred, poultry can be used to advantage at any time of the year, except possibly during the winter months when the grubs are deep in the ground, by permitting them to follow the plow, cultivator, and harrow whenever possible.

In pasturing hogs it is well to keep in mind the following points: (1) Accustom the hogs to corn and grubs gradually, especially the former; (2) a water supply should be considered; (3) it is best to fence off a single portion of the field at a time in order to make the eradication of grubs uniform and complete and to avoid waste in hogging corn; (4) a supply of salt should be available to the animals at all times.

ROTATION OF CROPS

Rotations are especially important in avoiding white-grub injury. A rotation of oats or barley, clover, and corn has proved very satisfactory in some sections. Ground which is in cleanly cultivated corn or has a heavy stand of pure clover during the year the beetles are flying ordinarily will contain few grubs, since the beetles will not seek such land for laying their eggs, but prefer land in small grains or timothy, or covered with weeds. Land which is in oats, barley, or wheat during the flight of the beetles will contain many grubs, but if the grain is followed by clover, which is one of the least susceptible crops, the grubs will scarcely injure the clover. It is asserted that clover winterkills badly in southern Wisconsin, northern Illinois, and similar latitudes, but there is reason to believe that this is because the clover is not sufficiently vigorous to survive severe winters, and the remedy is liming or otherwise treating the land so as to grow a vigorous stand of clover. Aside from this rotation, it is desirable to arrange the crops so that the least amount of land will be in timothy and small grain the year the beetles are abundant, and the following year to plant corn on corn ground, and use for small grain and timothy the ground which was in these crops the previous year. Where hogs can be pastured on the land the fall previous to planting, as under the conditions discussed in the preceding paragraphs, less regard need be had to the selection of crops, since a thorough pasturing by hogs will practically eradicate the grubs.

FALL PLOWING

Where it is impractical to pasture hogs in an infested field or to follow the prescribed methods of rotation, some good can be accomplished by plowing the ground in the fall. Fall plowing previous to the time the grubs go deep into the ground to pass the winter—i. e., previous to October 10—as a rule will destroy many of the grubs and should be practiced whenever possible but should not be consid-

ered a panacea for the grubs. Ordinarily the best time to plow with this object in view is between October 1 and 10. The main point to be remembered is to plow before the grubs go below the plow line and as short a time before this as can be done.

Summer and fall plowing the year the grubs are changing to beetles is of special value, and every piece of ground which contained grubs in their injurious stage the previous year should be plowed, if at all possible, as soon after July 15 as is practicable, and the sooner this is done after that date the more thoroughly will the pests be eliminated. A plow which will break up the soil as it is overturned should be used, or if this is not possible the ground should be deeply disked after plowing in order to break up the soil and disturb the insects in it. Whenever a grub-infested field is being plowed, harrowed, or cultivated where chickens are available, these should have the run of the field.

COLLECTING THE GRUBS AND BEETLES

Where it is possible to secure cheap labor, collecting the grubs after the plow is practicable, especially where the grubs are numerous. In Europe children are often employed to gather grubs in this manner and to collect the beetles.

Collecting the cockchafer,[21] a beetle very closely related to the May beetle, is a common practice in European countries, but so far as known no attempt to collect May beetles on an extensive scale in the United States has ever been made. Three methods may be employed in beetle destruction: (1) Collecting from plants upon which they feed at night, (2) trapping at lights, and (3) poisoning their food plants.

In Europe beetle collecting has proved of value largely because the years of abundance of the beetles have been definitely known in advance, while in North America this has not been the case. Now, however, there is proof that the beetles occurring in such abundance in many parts of the United States in 1926 (the parents of the destructive generation of grubs in 1927) have a life cycle of three years, and it is reasonably certain that they will continue to be exceptionally abundant in these regions every three years unless killed off by their natural enemies, by artificial means, or by unfavorable climatic conditions. Beetle collecting in the Old World has also proved practicable, (1) because of the organized cooperative movement among the farmers for the collection of the beetles; (2) because a small bounty is paid for the beetles; and (3) because of laws which in some countries require each farmer to collect a certain quantity of the grubs or beetles each year. Only where whole communities or neighborhoods cooperate in the work is it effective.

In collecting from food plants large cloth sheets are placed under the tree and the latter jarred, or in the case of large trees individual branches may be shaken by using a long pole provided with a hook at the end. The beetles are then gathered up from the sheet and put in cans, bottles, or boxes and afterwards killed with the vapor of carbon disulphide. Killed in this manner they may be fed to

[21] *Melolontha vulgaris* Linnaeus.

chickens, pigs, etc., but if they are not to be used for such purposes they may be killed by dropping them in cans containing water and just enough kerosene oil to cover the surface. As a rule beetles are most abundant on the oak, walnut, poplar, hackberry, willow, ash, and elm. Collections may be made at any time during the night, but the best time for this work is in the early morning, before 4.30 o'clock, at a time when the beetles are easily jarred from the foliage. It is essential that collecting be begun as soon as the beetles appear in the spring—that is, before the beetles have begun to lay their eggs—and it should also be borne in mind that each female beetle destroyed early in the season means the destruction of from 50 to 100 grubs which she might have produced.

Light traps have not as yet proved satisfactory as a means of control against May beetles, the prime objection to this method being that the light attracts the males to the almost total exclusion of the females.

SPRAYING

Spraying trees upon which the beetles feed, with Paris green, lead arsenate, or similar arsenical, is effective against the beetles, but ordinarily this method is impractical owing to the large size of the trees, which would necessitate large and expensive power sprayers. After more definite knowledge of the preferred food plants has been obtained it may be found practicable in some localities to plant low-growing trees and shrubs about fields as traps for the beetles, which might then be destroyed by spraying.

SPECIAL DIRECTIONS

In those districts in which the grubs were abundant and destructive in known years certain special directions and precautions may prevent a repetition of damage. As has already been stated, the parents of the grubs of 1927 appeared in the spring of 1926 and laid the eggs which hatched into grubs. Practically no damage occurred that year, but in 1927, when about half grown, the grubs caused great loss. These grubs continued active in the spring of 1928 and injured certain early plantings, but by early June most of the grubs became more or less inactive and later changed to the dormant or pupa stage, transforming into beetles about August. They will remain in the soil as beetles over winter, and appear above ground in the spring of 1929.

The recommendations on page 26 will assist in preventing grub injury, especially in those localities (see figs. 7 and 8, p. 6) where the grubs make their appearance regularly each third year.

CONTROL OF WINGLESS MAY BEETLES

In some parts of the South, as in southern Texas, certain species of wingless May beetles are often prevalent and damage field and garden crops. Since these beetles are unable to fly but move from field to field on foot, they are amenable to control by methods entirely impracticable in the case of the winged species. It has been found possible to poison them very successfully by means of a poisoned bran mash. Where an outbreak of these beetles originates in a field,

this should at once be treated by distributing a bran mash composed as follows:

Wheat bran	pounds	20
Paris green	pound	1
Sirup	quart	1
Lemons	fruits	3

Water sufficient thoroughly to dampen the mixture may be added where desirable. The fruit should be ground and added to the bran and Paris green after these have been thoroughly mixed.

This bait should be scattered broadcast at the rate of from 7 to 10 pounds to the acre, during the early hours of the evening, just before dark. Where the beetles are moving from one field to another it is easy to trap them by plowing deep furrows in the path of their advance. Such furrow traps should have their bottoms smoothed with a shovel but the sides should be left loose so as to hinder the beetles from climbing out of the ditch. If post holes are then dug in the bottom of the furrow at intervals of 15 to 20 feet, the beetles will fall into them and may be destroyed with kerosene or crushed with a heavy stick. It has been found useful to scatter the poisoned bait along the borders of the furrow, as this seems to add to the percentage of the kill secured.

CONTROL OF WHITE GRUBS ON GOLF GREENS AND LAWNS

Lawns destroyed by grubs should be resodded or reseeded, the old sod being first removed and the grubs gathered by hand, or killed with one of the soil insecticides later discussed. If poultry, especially turkeys, are allowed the run of the ground as the old sod is being removed, they will do the work in a thorough manner if no poison has been used. If the infestation is slight, liberal applications of a commercial fertilizer will assist the grass in overcoming the grub injury.

Soil Insecticides

Kerosene emulsion, sodium cyanide in solution, and carbon-disulphide emulsion have all given good results. The last is apparently the most satisfactory if the equipment and materials are available. For other conditions especially in lawns and similar small areas, the sodium-cyanide treatment is simple and easily available.

KEROSENE EMULSION

Kerosene emulsion has been recommended repeatedly as an effective grub insecticide. The department's tests indicate that it is satisfactory against grubs if thoroughly applied when the grubs are near the surface and the emulsion then washed well into the soil by copious sprinkling. Watering washes the emulsion from the grass and prevents burning and at the same time permits the insecticide to penetrate more thoroughly into the soil. For small areas an ordinary sprinkling can may be used in applying the emulsion, but for larger areas the use of a force pump will save time and labor, a wide sprinkling can type of nozzle or " rose " being used, so that the lawn can be uniformly drenched in the shortest possible time.

Kerosene emulsion is prepared as follows: One-half pound of hard soap or 1 quart of soft soap, preferably fish-oil, rosin-soda, or rosin-

potash soap, is dissolved in 1 gallon of boiling water, and while hot 2 gallons of kerosene are added and the mixture thoroughly emulsified. This may be done most easily and thoroughly by churning for about 10 minutes with a spray-pump, the nozzle being turned back into the liquid. When thoroughly emulsified the preparation will have the consistency of thick cream, and the oil will not separate. Danger of injuring plants is great if the mixture is not well and thoroughly made. For a 7½ per cent emulsion add 25 gallons of water to the above stock solution and mix thoroughly. It is desirable to use soft water both for the stock and for diluting, but where this is not obtainable the water should be softened by adding lye or sal-soda. A much better emulsion, apparently more effective and more easily made, is prepared by the use of fusel oil. It is prepared by dissolving 3½ pounds of fish-oil soap in enough water to make a gallon, adding 1 quart of fusel oil and then 2 gallons of kerosene. When this is churned thoroughly and emulsified, add 25 gallons of water, to make approximately a 7½ per cent emulsion.

SODIUM CYANIDE AS A MEANS OF CONTROL

Although such a dangerously poisonous substance as sodium cyanide can not be recommended for general use, its application in the case of infestations in golf greens has resulted in satisfactory control without permanent injury to the grass and without danger to players. The application of sodium cyanide in water seems to offer an efficient means of killing the grubs in large numbers where it is not possible to apply the cultural or other measures recommended for use on the farm.

The poison may be prepared by dissolving 10½ ounces of sodium cyanide in 50 gallons of water. Apply 1 quart of the solution per square foot of infested territory, with an ordinary hand sprinkler, afterwards sprinkling with water to wash the poison from the foliage so that it will not burn the tips of the grass. Where it becomes necessary to treat extensive areas, the use of a 600-gallon tank sprinkler, fitted with a 3-inch pipe 7½ feet long, running across the back of the tank, is advised. The sprinkler pipe should be pierced with three rows of ⅜-inch holes averaging 48 to the foot. With this equipment the proper dosage may be applied, the sprinkling apparatus being driven at a walking pace, or about 4 miles per hour. Where it is desirable to prepare large amounts of sodium-cyanide solution, this may be done by dissolving 160 pounds of the chemical in 12,000 gallons of water, the amount named being ample for about 1 acre. The cost of such application is high, running from $75 to $90 per acre, and therefore will not be justified except under extraordinary conditions, where it is determined at all hazards not to disturb the sod in order to effect control.

The poison when applied at the rate mentioned above disappears from the soil within 10 days to two weeks. Its application will be of avail only while the grubs are near or at the surface of the soil, that is to say, during the growing season.

WARNING: *Where sodium cyanide is to be applied, the utmost care in handling and applying it should be exercised, as it is one of the most powerful and deadly poisons known to man and a very small portion of it if taken internally will cause death almost instantly.*

CARBON-DISULPHIDE EMULSION

An emulsion of carbon disulphide with soap and water has shown high efficiency as an insecticide against white grubs in general. The emulsion may be prepared as follows:

Rosin fish-oil soap (cold-water soluble)	part by volume	1
Water	parts by volume	3
Carbon disulphide	do	10

Place the soap and water in a wooden churn or an ice-cream freezer and turn the handle for a few minutes in order to obtain an even mixture. Add the carbon disulphide to the mixture in the machine and turn the handle for two minutes or until the mixture becomes creamlike and thoroughly emulsified. Add 1 quart of this mixture to 50 gallons of water and apply to the infested lawn at the rate of 3 pints to the square foot of surface.

For small areas this liquid may be applied with an ordinary sprinkling can, but great care should be taken not to apply more than one layer of the liquid, as otherwise severe burning almost surely will result.

As the cost of this treatment is rather high, it may not be found practicable except for highly valued lawns or golf greens. One quart of the emulsion costs about 17 cents and 9 quarts will treat about 1,200 square feet of turf at a cost for materials alone of $1.53, or $55.50 per acre. The same care as regards fire risk should be taken in handling carbon disulphide as is necessary with gasoline. The surface treated with this liquid should not be sprinkled or watered for 36 hours after treatment, as watering is likely to interfere with the efficiency of the kill secured.

In attempting to apply insecticides for white grubs, especially on golf links, care should be taken to differentiate between the work of these pests and that of the grubs of the green June beetle. The grubs of the latter insect are often present in lawns and on the links but do not attack the roots of the grass at all. They are troublesome principally because of the large amounts of earth which they throw up at the mouths of their burrows, thus interfering with the play and covering the grass with mud during damp weather. These grubs become of much larger size than the white grubs and construct deep vertical burrows in which they hide throughout the late summer, fall, and winter. When deep in the ground they can not be reached effectively with most insecticides but yield to the methods advocated for white grubs in midsummer, when they are near the surface and therefore more accessible.

It might be mentioned here that carbon disulphide may be injected with excellent results into the holes of the grub of the southern green June beetle, which is frequently quite injurious to lawns and golf greens in the Southern States. Kerosene emulsion likewise has given excellent results against this grub.

GRUB-PROOFING LAWNS

In preparing ground for sod it may be made proof against underground grubs and worms, and without harm to the common grasses, by mixing lead arsenate with the upper soil layer. At the same time

the commoner weeds, such as crab grass, dandelion, sour dock, etc., do not grow well in poisoned soil. This treatment will be effective for at least five years and probably much longer.

Treatment is given at the time the ground is being prepared for seeding and can not be used directly on the sod. Lead arsenate is applied evenly at the rate of 1,500 pounds to the acre (3½ pounds per 100 square feet). To obtain a more uniform distribution it is first mixed with a small quantity of loose, dry soil or sand, about a cubic yard for every 150 or 200 pounds of lead arsenate. As soon as it is spread over the surface it should be worked in to a depth of 3 inches, after which the soil is ready for seeding.

If it is desired to make treatments direct to growing sod, use the poison at the rate of 5 pounds of lead arsenate to each 1,000 square feet, first mixing this quantity of the poison with a bushel of top soil or dressing, and then applying it evenly over the sod. This should be done in the spring and fall and again the following spring.

Care should be used in fertilizing before or after treatment. Ammonium sulphate and well-rotted manure may be used, but lime, super-phosphate (acid phosphate), potash salts, and mixed fertilizers can not be used in the same soil with lead arsenate.

CONTROL METHODS TO BE ADOPTED FOR ALL STAGES OF THE WHITE GRUB

SMALL GRUBS ABUNDANT IN FALL

Plow infested grass and small grain land previous to October 1, as this destroys recently hatched grubs. Seed the land so treated with small grain or clover for the following year. Do not plant corn or potatoes on land infested with white grubs. Pasture hogs and allow chickens to run in the fields when cultivated.

SMALL GRUBS ABUNDANT IN SPRING

Where small grubs are found abundantly during the spring this indicates the likelihood of heavy damage during the approaching summer, as the grubs will become large enough to be destructive to live roots. Sow land infested in this manner to small grain or clover. Do not plant corn or wide-row crops on such land. Plant corn, potatoes, field beans, etc., on ground that has been clean-cultivated during the preceding year. Pasture hogs on infested ground.

LARGE GRUBS ABUNDANT IN FALL OR SPRING

When large grubs are abundant in fall or spring this indicates that the insects are about to transform to the pupa stage. These grubs may be expected to inflict some damage but by June 15, or soon thereafter they cease feeding and prepare to become pupae and beetles. Plow land infested in this manner about October 1. Where ground is infested with large grubs in the spring it should be plowed as soon after July 15 as practicable. Pasture with hogs where possible.

BEETLES OR PUPAE IN GROUND IN SUMMER

Plow thoroughly, so as to break the clods subsequent to July 15; the sooner after that date the better. Pasture with hogs where possible.

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